PUTTING RESEARCH TO WORK

BRIEF

Earlier Opening a Possibility for Urban Concrete Pavements

Minimizing the impact of curing time for concrete pavement structures is an ongoing challenge in building highways. Depending on air temperature and pavement thickness, portland cement concrete pavements can remain closed from seven to 21 days after pouring, preventing construction crews from finishing work, hampering drivers, and impeding access to local businesses and residences. Wisconsin DOT requirements set concrete curing periods based on prevailing air temperatures or data from test cylinders from the construction site (the concrete must reach a compressive strength of 3,000 psi prior to opening to traffic).

What's the Problem?

Strategies such as fast-track paving operations and the use of high early-strength concrete have reduced the delay between paving and curing, but increased early strength generally results in a slight reduction in the ultimate strength gain of most concrete mixtures. In some cases this may reduce a pavement's fatigue life by three to five years.

Early opening of concrete pavements to traffic naturally appeals to WisDOT, even if it requires tiering traffic to minimize load impact early in the new pavement's life. But early opening could induce excessive bearing stresses, leading to micro- or macrocracking in the concrete around the dowels that might not be visible at the surface but could hamper load transfer and shorten pavement life. Current methods of determining these stress levels prove too complex for routine use.

Research Objectives

This research aimed to evaluate the viability of early opening of concrete pavements to traffic. The research had three objectives. The first was to determine early-age strength gain for selected PCC pavement mixtures used in Wisconsin. The second was to determine early-age loading effects on doweled pavement joints, specifically excessive bearing stress on the concrete around and below the dowel bar. The last was to establish compressive strength requirements and assessment procedures that could be used to open concrete pavements based on early strength.

Methodology

This research included four segments:

Bearing stress analysis. Researchers completed a literature search to identify the best methods of determining critical dowel bearing stresses. They then performed finite-element modeling of typical PCC pavement structures to develop a simplified procedure for estimating stress around dowels from early-age loading.

Field study. Investigators used materials from four WisDOT concrete paving projects to fabricate test specimens, including cylinders, beams, and exposed dowel specimens. The cylinders were covered with clear plastic bags and cured alongside the mainline pavement. The plastic bags created a terrarium effect that helped prevent moisture loss and maintain cylinder temperatures. Maturity readings in the cylinders and mainline pavement validated this method as a way to check the early-age compressive strength gain of the mainline pavement.

Laboratory testing. Researchers tested the fabricated specimens in the lab to assess relationships between strength measures and maturity, a concept that factors in both time and temperature.

Analysis. From field and lab test results, researchers developed equations for predicting early-age compressive strength from seven-day and 28-day lab tests. They also established appropriate timing for quality assurance testing.

Investigator

"For urban sites where it's critical to open roads quickly, we found that certain doweled concrete pavement systems should reach opening strength a few days sooner than WisDOT currently allows."

–Jim Crovetti
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Researchers used exposed-dowel concrete specimens to test the long-term effects of early-age loading on doweled joints (Fig. 3.4.1, page 71 of the final report).

Results

This project developed equations for predicting early-age compressive strength from lab test results, and found that some pavements may be opened to traffic earlier than WisDOT's current practices allow. Detailed findings included:

Early-age strength gain

- Cylinder compression strength testing within the first 28 days of curing can predict flexural strength and fatigue resistance.
- Placing test cylinders in plastic bags for field curing effectively simulates the curing conditions of the mainline pavement, as validated by maturity readings in the cylinders and the mainline.
- Researchers developed equations for predicting early-age PCC compressive strength from seven-day or 28-day laboratory test results. These equations can be used to help establish appropriate times for quality assurance testing. Estimating seven-day early-age strength based on maturity readings of field-cured bagged cylinders was most effective.

Early-age loading effects on doweled pavement joints

- This project produced a simple procedure for predicting stresses at the interface of concrete and dowels. However, exposed dowel load and deflection tests correlated poorly with strength and maturity tests and failed to identify compression zone failures. More research is needed to develop appropriate testing protocols and guidelines for implementation.

Compressive strength requirements

- Researchers found that the PCC compressive strength required to protect against excessive dowel bearing stresses was dependent on three key pavement parameters: slab thickness, dowel diameter and subgrade support.
- For thicker PCC pavements constructed with 1.5-inch dowels, opening compressive strengths as low as 2,300 may be adequate—significantly lower than the minimum opening compressive strength of 3,000 psi that WisDOT now requires. For PCC pavements that use 1.25-inch dowels, research confirmed that the minimum opening compressive strength should remain at 3,000 psi.

Implementation and Benefits

By lowering the minimum opening compressive strength required for thicker concrete pavements with 1.5-inch dowels, WisDOT may be able to open these pavements to traffic a few days earlier than current practice permits. Drivers, businesses and residents will benefit through reduced construction times, and road builders will be able to install roads more quickly, ultimately saving taxpayer money.

This brief summarizes Project 0092-01-04, "Early Opening of Portland Cement Concrete Pavements to Traffic," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research, Development & Technology Transfer Program, 4802 Sheboygan Ave., Madison, WI 53707.

Nina McLawhorn, Research Administrator

Project Manager

"The findings were pretty conclusive. For pavements under 10 inches thick, we're pretty close on our recommendation for opening, but on heavier pavements, we may be able to shorten the time until opening."

–Jim Parry
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